Anatomy of the Abdominal Wall

Introduction

The abdominal wall contains unique structures that are not seen elsewhere in the body. Getting to any of the abdominal organs involves going through the abdominal wall—skin, fat, muscle, and fascia. The abdominal wall is supposed to keep the abdominal contents contained and also protected from anything outside the abdominal compartment. Given the unique and complex anatomy of the abdominal wall, it becomes a commonly tested topic on licensing examinations. Clinically, the abdominal wall is extremely important in the healing of abdominal incisions (aka surgery) and the formation of hernias.

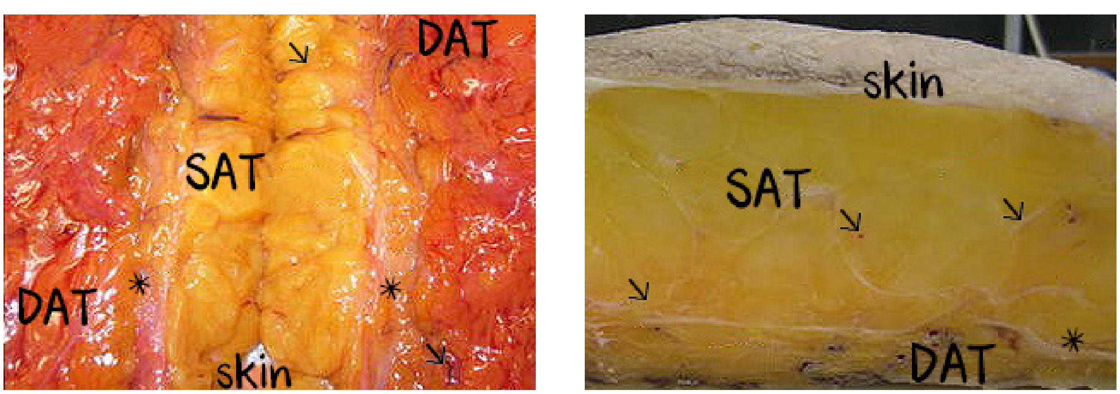
We start with some basic anatomy—the fascia and muscles of the abdominal wall. We then identify certain geographic landmarks of significance—the inguinal triangle, the femoral triangle, and the inguinal canal. We then use that information to engage the topic of hernias in the next lesson.

Superficial Fascia

In the abdomen and only in the abdomen, there are **two superficial fascial layers**. If a surgical incision is performed anywhere, the scalpel cuts through the skin: epidermis, dermis, and hypodermis. The hypodermis is the subcutaneous fat. Over the abdomen, that same hypodermis, aka the subcutaneous fat, is called **Camper's fascia**. It gets a special name over the abdomen because under the skin that lines the abdominal muscles (and covers the peritoneal cavity) is the second layer of fascia, which is separate from and not continuous with the subcutaneous fat, called **Scarpa's fascia.** This is a thin membranous layer. Beneath Scarpa's fascia is another layer of adipose tissue. Recent strong evidence has supported the replacement of the eponyms with descriptive names: a layer of superficial adipose tissue (SAT), a membranous layer (ML), and a layer of deep adipose tissue (DAT). We strongly agree.

Over the abdomen, the layers are, from the outside in towards the abdominal muscles, **skin** (epidermis, dermis), **superficial adipose tissue** (hypodermis), a **membranous layer** that separates the SAT on a different plane than the **deep adipose tissue**, loose connective tissue (fascia), then muscle (or tendon).

The SAT (Camper's fascia) is adipose. It is the connective tissue through which cutaneous blood vessels, lymphatics, and nerves flow. This same layer of tissue is where the arteries and nerves of the muscles run. It is **the same continuous layer** in the rest of the body. The subcutaneous fat and connective tissue that is Camper's fascia of the skin over the abdomen is the subcutaneous fat and connective tissue of the skin over the rest of the body. What that means is that in the abdomen, there is something added.

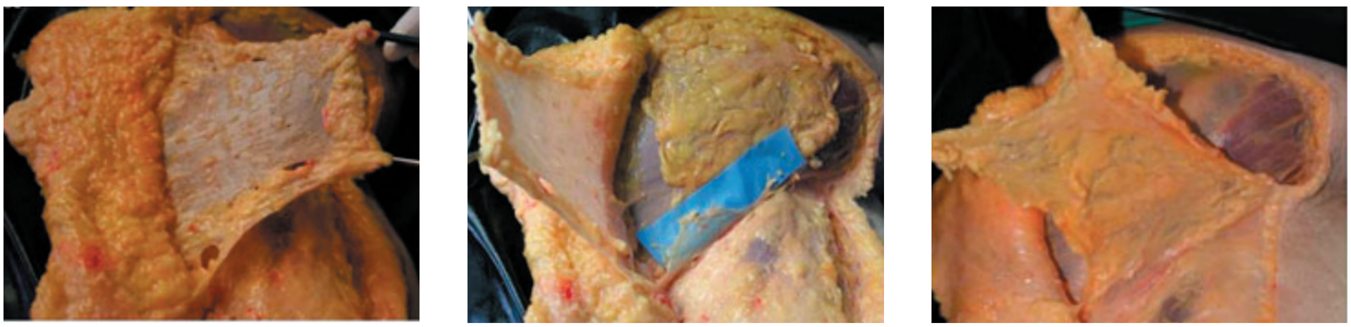


(a) (b)

Figure 1.1: Superficial Fascia
(a) "Surgical" description of abdominal subcutaneous tissue; a fresh full-thickness specimen, reversed and cut perpendicularly to skin. (b) Slice of a formalin-fixed specimen. SAT, superficial adipose tissue; DAT, deep adipose tissue; stars, membranous layer; arrows, retinacula cutis.

The ML and DAT follow the same path, but a different path than the SAT. They are present only under the skin overlying the abdominal compartment. Wherever there is abdominal muscle, the DAT and ML will form. Wherever there is underlying parietal peritoneum—mesothelium—against the chest wall (beneath the muscles), there will be ML and DAT above the muscle. As seen if dissected above the diaphragm or below the inguinal ligament, there is a sharp demarcation—they disappear. The DAT disappears, and the ML becomes continuous with the tendons of the abdominal muscles.

So, rather than what is traditionally taught (Camper's and Scarpa's), we want you to think like this: anywhere there is skin, there are subcutaneous fat and connective tissue that carries blood vessels, nerves, and lymphatics. That is the SAT, and it is everywhere that skin is. Over the abdomen, there is an additional layer of membranous fascia and DAT that covers the abdominal muscles.



(a) (b) (c)

Figure 1.2: Fascial Layers Traced
The superficial fat layer, Camper's fascia, is continuous with the fascia of the thigh. The membranous fascia (Scarpa's) and the deep adipose layer end abruptly at the edge of the abdominal cavity.

The main clinical significance of this is in the healing of a surgical incision. When the surgery is over, the surgeon must close the incision and overlying skin. There are two types of closure—mass closure and individual fascial closures. Each has theoretical risks and benefits, although to date, studies have not found there to be an actual difference in outcomes, and research is ongoing. Suturing two ends of a layer together comes with the intention that they will scar together. Doing this on individual layers (peritoneal aponeurosis, superficial aponeurosis, ML+DAT, SAT, skin) ensures that the suturing won't be too tight, the risk of edema and necrosis will be small, and if any one layer fails, the wound won't open. Doing this in mass closure (everything except skin first, then skin) is faster and cheaper (only one suture is used), but carries a risk of dehiscence—if the one suture fails, the bowel is exposed to the atmosphere. Doing it in individual layers takes more time, but prevents dehiscence, and allows for individual layers to fail. Individual fascial layers are therefore associated with higher risks of seromas and ventral hernias but decreased complete dehiscence.

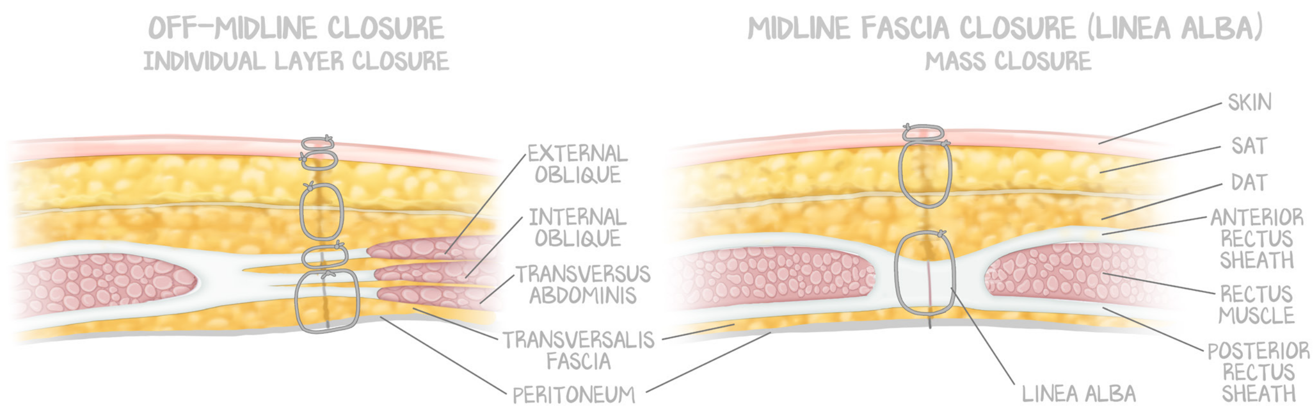


Figure 1.3: Layered Closure
Surgical incisions may be either layered (deep aponeurosis with peritoneum, superficial aponeurosis, DAT/SAT) then skin, or en mass (muscles, fascia) then skin. This illustration depicts two different closures at two different incisions (midline and off-midline). Either closure can be used at either incision site; the goal was to demonstrate possible permutations and not to link a closure type with an incision location.

In clinical practice, as recommended by surgical societies, when it comes to closing a surgical incision, what's more important than how many layers are closed at once are the following four things: using a small-bite technique (tie up the incision tighter, with more bites), ensuring a minimum of 4:1 suture length to incision length ratio (extend the suture past the incision), closing with a continuous suture technique, and using slowly absorbable monofilament as the suture type. You are unlikely to be tested on the correct surgical closure technique, but anyone who will ever cut skin should know how to close skin.

Muscles of the Abdominal Wall

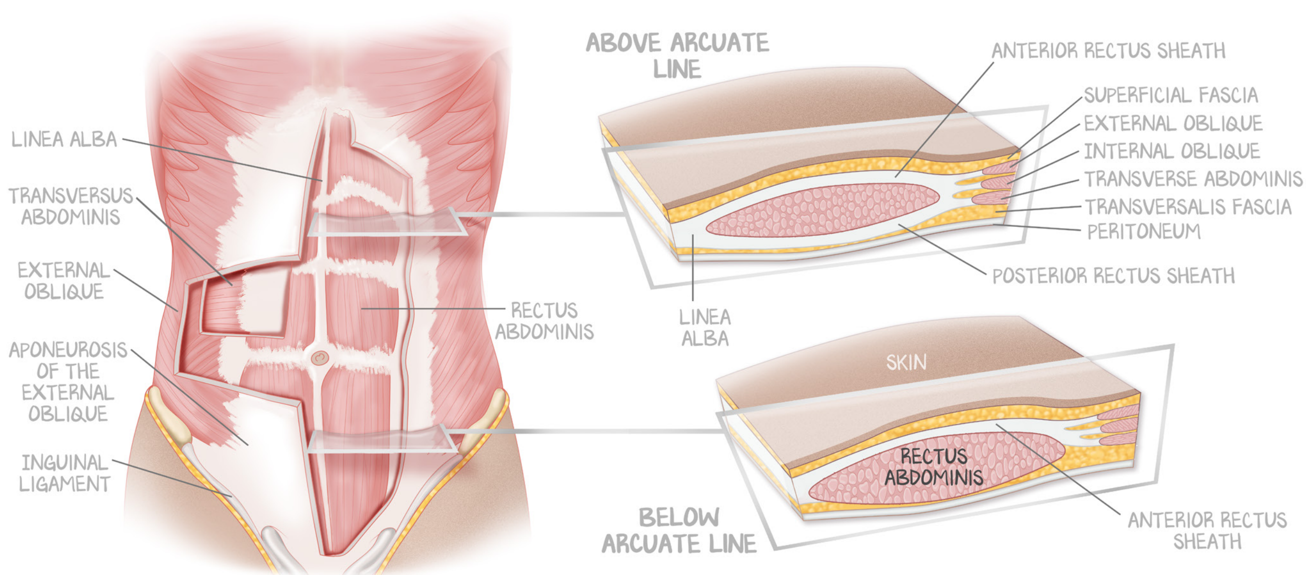


Figure 1.4: Muscles of the Abdominal Wall
A visualization of the muscles of the abdominal wall. The external oblique muscles are the most superficial and form the inguinal ligament with their aponeuroses. The internal obliques are deep to the external obliques and superficial to the tranversus (aka transversalis) abdominis muscle. Eight rectus abdominis muscles are seen, with the muscles resected for visualization. They all coalesce in the middle, the linea alba.

There are three flat muscles on either side of the abdominal wall. From the most superficial to the most deep, there are the external oblique, internal oblique, and transversus abdominis. They are flat muscles, and so have flat tendons. This special flat tendon is called an **aponeurosis**. Abdominal muscles ARE special. They do not attach bone to bone like all other muscles. They originate from bone, but insert into a common aponeurosis in the middle, called the **linea alba**. The linea (line) alba (white) runs from the xiphoid to the pubis. It is the thing into which the flat muscles' aponeuroses insert, and it is also made of those aponeuroses.

The **rectus abdominis** (plural *recti*) is the **vertical** abdominal muscle. There are eight of them. These are your "abs" and the bodybuilding hopeful's dream of a "six-pack." There are eight. Not six. Beer comes in six-packs. Abs come in eight-packs (except for Lego Batman, "*yeah, I've got an extra ab*"). They are connected to each other by connective tissue, a "tendinous intersection" (an aponeurosis, but it gets a special name). There are four muscles on the right and four on the left. They have an aponeurosis between them, vertically, the linea alba. They are in the plane of the **internal oblique**, under the external oblique, and above the transversus abdominis.

Around the rectus abdominis is the aponeurosis of the flat muscles. The aponeurosis of the flat muscles that wraps around the rectus abdominis is called the **rectus sheath**.

The **inguinal ligament** connects the ~~posterior superior iliac spine~~ to the anterior superior iliac spine. This ligament is a ligament because it connects bone to bone. It is formed by the inferior border of the external oblique aponeurosis. The ligament is ALSO the tendon of one of the external oblique muscles.

The Arcuate Line

The rectus sheath is the name for the aponeurosis of the flat muscles when the aponeurosis is either under or above the rectus abdominis. The aponeuroses of the flat muscles come from the sides to meet in the middle, at the linea alba. The rectus abdominis muscles are part of the mish-mash. The flat muscles don't meet deep or superficial to the rectus muscles; they go through the plane of the rectus muscles, encircling them, fusing their aponeuroses with the aponeuroses of the recti.

At the **arcuate line** (somewhere **below the umbilicus** and **above the pubis**), how the flat muscles' aponeuroses interact with the recti abdominis changes. The arcuate line is the site where the inferior epigastric vessels enter the rectus sheath and pass upward to anastomose with the superior epigastric vessels. The inferior epigastric vessels exit the external iliac artery just as the arteries leave the abdominal cavity through the femoral canal, just under the inguinal ligament. The arteries then ascend the inside of the abdominal wall, above the mesothelium lining the peritoneal cavity but below the transversalis fascia. They then reach the arcuate line and are enveloped by the rectus sheath.

Above the arcuate line, the aponeuroses of the flat muscles act independently. The **anterior rectus sheath** above the arcuate line is made of the **external oblique** and **half the internal oblique**. The **posterior rectus sheath** above the arcuate line is made of **half the internal oblique**, the **transversus abdominis**, and the **transversalis fascia**.

Below the arcuate line, the posterior rectus sheath consists of **only the transversalis fascia**. Guess what? The transversus abdominis is also called the transversalis muscle. Thanks, antiquated medical science. If only someone could figure out what things in GI should be called and actually name them correctly. The muscle of the transversus abdominis (sorry, transversalis muscle) is anterior to the recti abdominis. The fascia of the transversalis (sorry, transversus abdominis) is posterior to the recti abdominis. Fascia is a flimsy, sinewy, white (when not with adipose) and yellow (when with adipose) layer of connective tissue. Surgeons see it and sometimes dissect it away.

The transversalis fascia (sorry, fascia of the transversus abdominis) is a thin membrane of aponeurosis tissue, the amorphous connective tissue that separates the muscles of the abdominal wall from the mesothelium lining the peritoneal cavity. That means that if a laparoscopic camera is within the peritoneal cavity and looking up at the abdominal wall, then between the camera and the rectus abdominis, there is only a sheet of simple squamous epithelium (mesothelium, called the peritoneum in this body cavity), transversalis fascia, and some adipose. A surgeon doing a hernia surgery laparoscopically, which occurs far below the arcuate line, must dissect away the sinewy, white and yellow crap to get to the hernia. That surgeon doesn't cut the other muscles. Some surgeons call this adipose-and-stringy-clear-crap-in- their-way "fascia," and others call it "peritoneum." All of them are wrong. It definitely IS the adipose- and-stringy-clear-crap-in-their-way that they must clear away to get to the hernia they are going to fix. Technically, what they cut away is both the peritoneum (the simple epithelium) and fascia (adipose, stringy membrane stuff). This is not a dig at surgeons. They must clear that stuff out of the way to fix the hernia. It probably serves no purpose (this is now debated, but it *probably* serves no purpose). But as a novice learner (and as a very experienced learner in the case of Dr. Williams, who had the same problem figuring this stuff out), hearing the wrong words being used the wrong way to explain something that everyone who already knows understands (peritoneum being the yellow and clear fascia and not the sheet of mesothelium lining the peritoneal cavity) is immensely confusing.

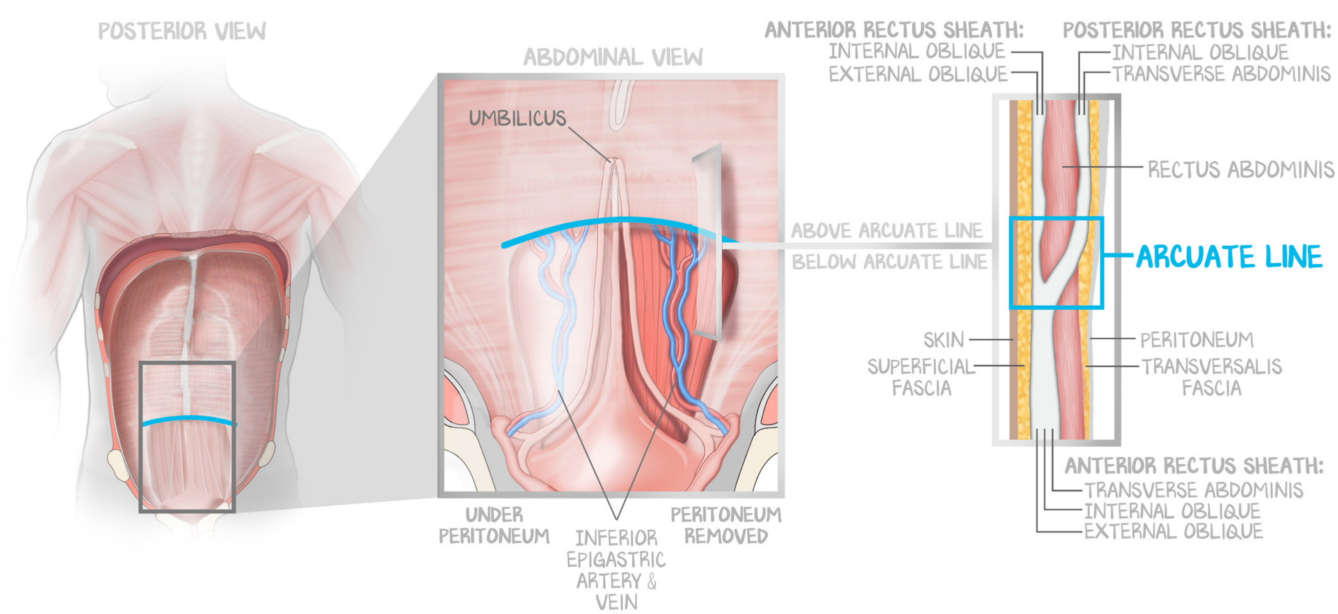


Figure 1.5: The Arcuate Line
Above the arcuate line, the inferior epigastric vessels run within the rectus sheath. Below the arcuate line, those vessels run along the posterior rectus abdominis. That is because the rectus sheath consists of an anterior sheath and posterior sheath above that line, and an anterior sheath and merely peritoneum posterior to the rectus below that line.

The "peritoneum" is the name of the mesothelium-that-lines-Body-Cavities when that cavity is the peritoneal cavity. The fascia is the nebulous connective tissue of sinewy white-to-clear junk mixed with yellow junk that definitely isn't muscle. This stuff has a purpose. Medical science doesn't understand it well because it was (and mostly still is) just the "white stuff you tossed out during anatomy lab," and "the stuff that needs to be dissected to get to the hernia."

The reason that this fascia matters to you is because fascia and aponeurosis of muscles are effectively the same thing—weak, flimsy, and easily perforated. Above the arcuate line, muscle and fascia protect the abdominal wall from herniation. Below the arcuate line, there is a teeny tiny "*hernia hideout*" where there are no muscles to prevent bowel-covered-in-mesothelium from slipping through. We talk even more about hernias in the next lesson. The remainder of this lesson is the details of the "*hernia hideout*"—inguinal canal, inguinal triangle, and femoral triangle.

Inguinal Canal

The inguinal canal is what the testes descend through in males. The testes, their blood supply and lymphatics, the cremaster muscle, and the rest of the spermatic cord are connected to the abdomen via the inguinal canal, a tunnel in the inguinal ligament.

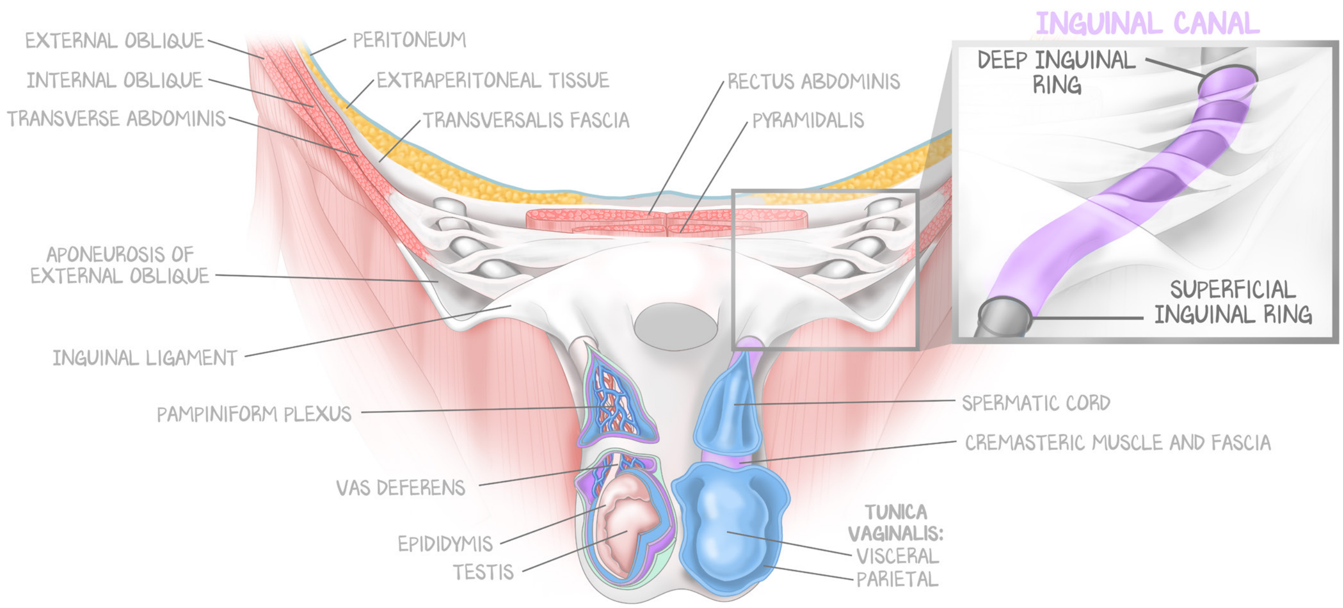


Figure 1.6: Inguinal Canal and the Spermatic Cord
This is a busy slide and a difficult concept for most learners. In the zoom box, the inguinal canal is depicted as a purple tube running through the various aponeuroses of the abdominal muscles. The purple tube is the outside of the spermatic cord. This schematic representation shows the deep inguinal ring laterally, the course of the inguinal canal, and its exit through the superior inguinal ring medially to the canal's origin. In truth, the canal and, therefore, the spermatic cord, are made up of those aponeuroses (below). The spermatic cord on the patient's right shows the tunica vaginalis resected, revealing the vas deferens, epididymis, testis, and the blood vessels contained within the cord.

To understand how this canal works, that is, what the layers are, we are going to do a thought exercise. The testes don't drill their way through the abdominal wall during development; they gently push on it. They push from the inside of the abdomen outwards. When they push gently, the fascia stays intact and comes along for the ride. We did the last section from the skin into the abdomen. We then showed you the view from the intestines. That view, looking out at the abdominal wall, is the same view the testes have.

Lateral to the inferior epigastric arteries is where the testes start to push. The **deep ring** of the inguinal canal (called deep because it is farthest from the surgeon on the outside of the patient) is **lateral** to the epigastric vessels. The first thing the testes find is the **transversalis fascia**. They push gently, so the transversalis fascia comes along for the ride. Now, the testes-covered-by-transversalis-fascia push. They push into the transversus abdominis muscle. Pushing gently, it comes along for the ride. Now the testes-covered-by-transversalis-fascia-covered-by-transversus-muscle push into the internal oblique muscle. They push gently. It comes along for the ride, the internal oblique being the farthest thing from the testes and the closest to the next layer. They push into the aponeurosis of the external oblique.

Aponeurosis is fascia. They push through the **superficial inguinal ring**, which is just superior to the pubic tubercle. Into the skin sac that is the scrotum they go. And they descend.

The spermatic cord that is formed carries the blood vessels, lymphatics, nerves, and ductus deferens (Reproduction: Male Reproduction #1: *Normal Testis*) from the abdomen down into the scrotum. From the inside of the tube that is the spermatic cord looking out, there is going to be the **internal spermatic fascia** made from the **transversalis fascia**. The first thing you see is the first thing you passed through. After the internal fascia is the **cremaster muscle and fascia**, made from the transversus and internal oblique. The two muscles that were passed after the transversalis fascia form the only muscle in the spermatic cord. Finally, there is an **external spermatic fascia** formed by the **external oblique** aponeurosis.

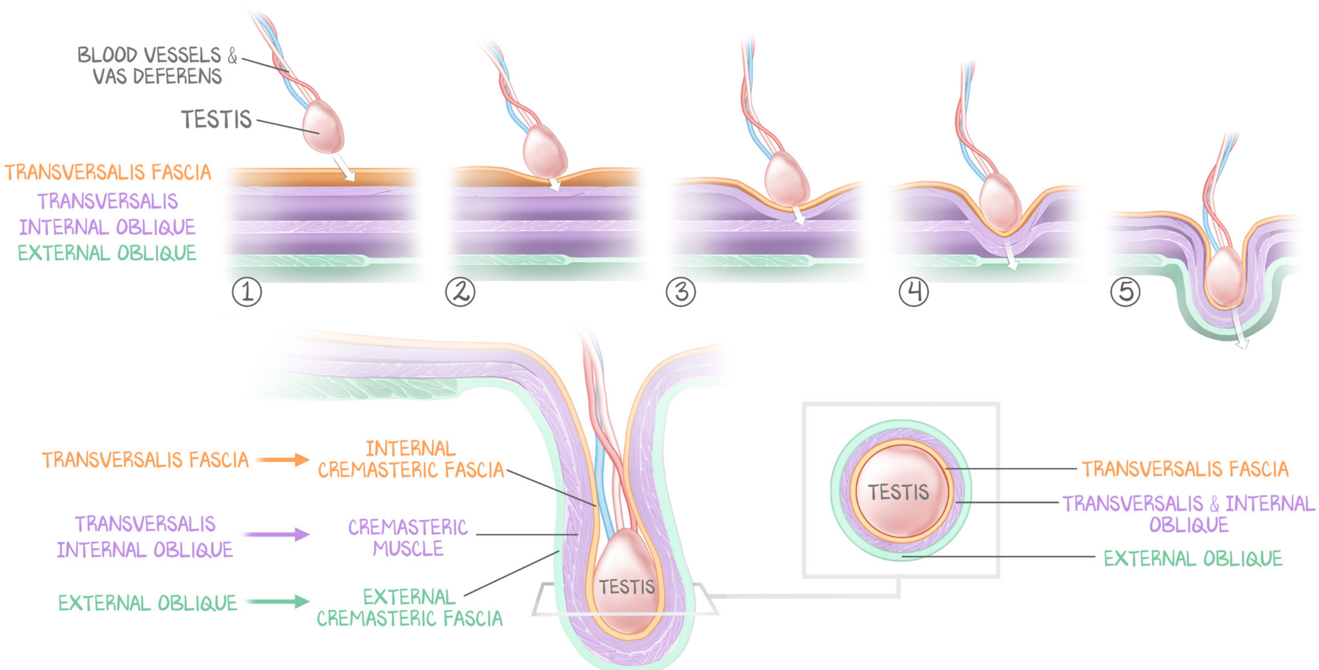


Figure 1.7: Flight of the Testes
A schematic of the process of testicular descent during embryogenesis. The point is to see that the layers of the abdominal muscles and their aponeuroses represent their corresponding structures, layered in the same order, in the spermatic cord. This isn't exactly what happens, but it is a mechanism to recall the layers of the spermatic cord and their origins, a commonly tested subject.

That's an easy way to get it straight, to see how the structures relate, but not what actually happens. What actually happens, in males and females, has to do with the processus vaginalis and the gubernaculum. Remember, there are TWO of these processes (not Processus Vaginalis, but processes, things, structures) occurring at the same time.

The **processus vaginalis** is a body cavity—it is lined with simple squamous epithelium (mesothelium) and contains fluid. The processus vaginalis is a growing body cavity during embryogenesis. There are two—one on each side of the body. Each is an evagination of the parietal peritoneum (the mesothelium that lines the peritoneal cavity that is in contact with the abdominal wall). The processus vaginalis induces the formation of the inguinal canal. Slithering under the parietal peritoneum, just beneath the processus vaginalis and on top of the transversalis fascia, is the testis and its vessels. It hops on the trail made by the processus vaginalis, and down into the scrotum it goes. Always outside the processus vaginalis, outside the body cavity. What should happen is that the entire length of the processus vaginalis, except the very distal end, should disappear by fusing the mesothelium, obliterating the lumen, and disconnecting the peritoneal cavity from what is left behind in the scrotum, next to the testis. The tiny Body Cavity, the mesothelium-lined and fluid-filled structure, is called the **tunica vaginalis**. Where the lining of that cavity bumps up against the testes, it is called the visceral layer, and where it is not touching the testes, it is called the parietal layer. That is a space, already with some fluid in it (opposed to a "potential space" as is often taught), in which extra fluid can accumulate, causing a **hydrocele** (more on this in Reproduction: Male Reproduction #3: *Scrotal Pathologies*). This Body Cavity was named the tunica vaginalis, so that's the name we're teaching you this early in the Organ Systems. However, at the end of Organ Systems, we will rename it more appropriately. This Abdominal Wall island will prepare you to accept that renaming.

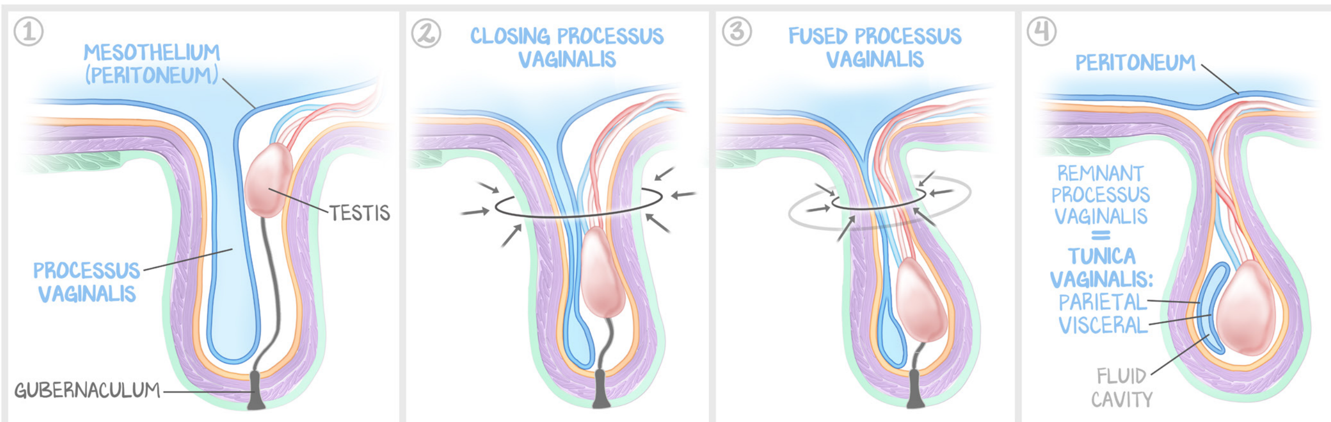


Figure 1.8: Processus Vaginalis and Gubernaculum
A more realistic representation of testicular descent. The gubernaculum induces the evagination of the inguinal canal as well as the evagination of the parietal peritoneum (the processus vaginalis). The gubernaculum acts as an anchor for the testis, which enters the evagination outside the processus vaginalis. When the testis is in place, the opening to the canals tighten, forcing the mesothelium of the processus vaginalis to collide, fuse, and disappear. The remnant of the peritoneal cavity in the scrotum is a Body Cavity—a mesothelium-lined sac of fluid—derived from the peritoneal cavity, which is also a Body Cavity.

Completely independent of the processus vaginalis is the **gubernaculum**. The gubernaculum is derived from mesenchyme. The gubernaculum is believed to play a role in forming a path through the anterior abdominal wall with the processus vaginalis, but it is definitely known to **anchor the testes** to the scrotum as they descend. Behind and outside the processus vaginalis, the testes descend attached to their blood vessels, lymphatics, and nerves. The testes migrate underneath the parietal peritoneum of the peritoneal cavity and processus vaginalis but above the transversalis fascia. The gubernaculum is the track the testes follow to arrive at their final resting place. This is how the vessels of the spermatic cord are found within the internal cremasteric fascia. After the testes have moved through the inguinal canal, the muscles of the inguinal canal constrict around the spermatic cord. The processus induced the evagination of the inguinal canal, and the gubernaculum drags in the spermatic cord, testes, and vessels.

Inguinal Triangle

Also called Hesselbach's triangle, the inguinal triangle represents an area of weakness in the abdominal wall. The rectus abdominis muscle is big, thick, and strong. No weakness there. The external oblique, internal oblique, and transversus muscles are big, thick, and strong. No weakness there. **Muscle** protects from herniation because it both causes and resists abdominal pressure. **Fascia** is what bowel herniates through. Aponeurosis of muscles is more like fascia than muscle. The only place in the abdomen where there is only aponeurosis and no muscle is at the inguinal triangle—an itty bitty, tiny spot of weakness. It is bordered by the **rectus abdominis muscle** medially, the **inguinal ligament** inferiorly, and the

inferior epigastric vessels laterally. That's right. Vessels. That's just how ol' Hesselbach described it. It isn't a real structure, and it doesn't serve a physiological purpose. It's just that surgeons noticed that hernias happened to go through the wall at that spot—**medial to the inferior epigastric vessels**—very frequently and came up with a way to communicate that location to other surgeons.

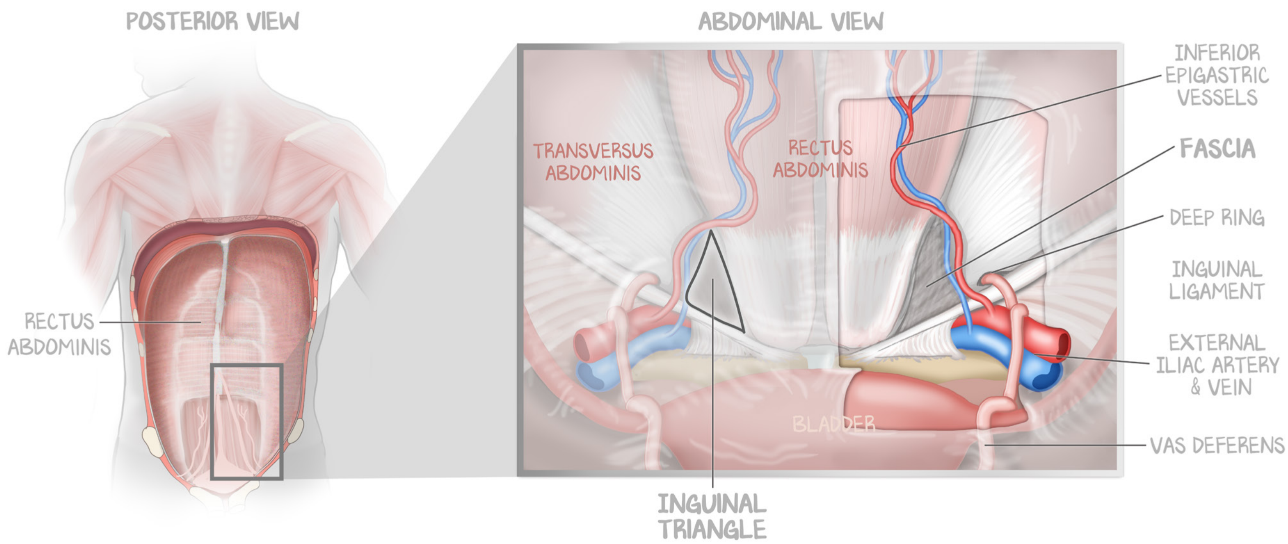


Figure 1.9: The Inguinal Triangle
The inguinal triangle is the site of direct hernias, a common site at which hernias occur. That is because that teeny tiny geographic location (relative to the abdominal cavity) represents a weakness in the abdominal wall muscles. It consists only of transversalis fascia—no rectus abdominis or other abdominal muscles between the peritoneum and the inguinal canal. The inguinal triangle is said to be bounded by the inferior epigastric vessels, the rectus abdominis, and the inguinal ligament. The deep inguinal ring of the inguinal canal is located lateral to the epigastric vessels, with the inguinal triangle medial. Also, notice the representation of the structures relative to the peritoneum. In the abdominal view, we share the perspective of the bowel, looking out towards the inside of the abdominal wall. All structures are on the other side of the peritoneum from us, those structures having mesothelium draped over them.

Femoral Triangle

The femoral triangle is flanked by the **inguinal ligament** above (superior border), the **sartorius** on the lateral side (lateral border), and the **adductor longus** on the medial side (medial border). The contents of the femoral triangle can be recalled with the mnemonic NAVEL, starting laterally and working your way medially towards the navel. Farthest lateral is the **femoral nerve**, then the **femoral artery**, then the **femoral vein**, then a big old **empty** space, then the **lymphatics**. That combination of empty space and lymphatics is called the **femoral canal**. The **femoral sheath** wraps up the artery, vein, and canal (which is empty space and lymphatics), and excludes the femoral nerve. This makes for some pretty convenient anatomy when placing a central line.

Before the days of ultrasound-guided central line placement, we used our hands. If standing on the patient's right side looking up towards their face, placing your left hand on the patient's right femoral pulse, you could use this anatomy to know the location of the femoral vein, the thing you want to put a needle into. You FEEL the artery, so don't stick there. The nerve is lateral, and with the orientation described and inserting the catheter with your right hand, it would be really hard to accidentally go too far laterally—your left arm is in your way. So, you go medial to the femoral pulse, where the vein should be. And if you happen to miss because you go too far medially, the only structure you compromise is the femoral canal, which is mostly empty space, so you do not damage any nerves and do not compromise the femoral artery.

Downside . . . Because blood vessels, lymphatics, and nerves exit the abdomen to enter the femoral compartment, it represents a site of weakness, through which a hernia sac can protrude.

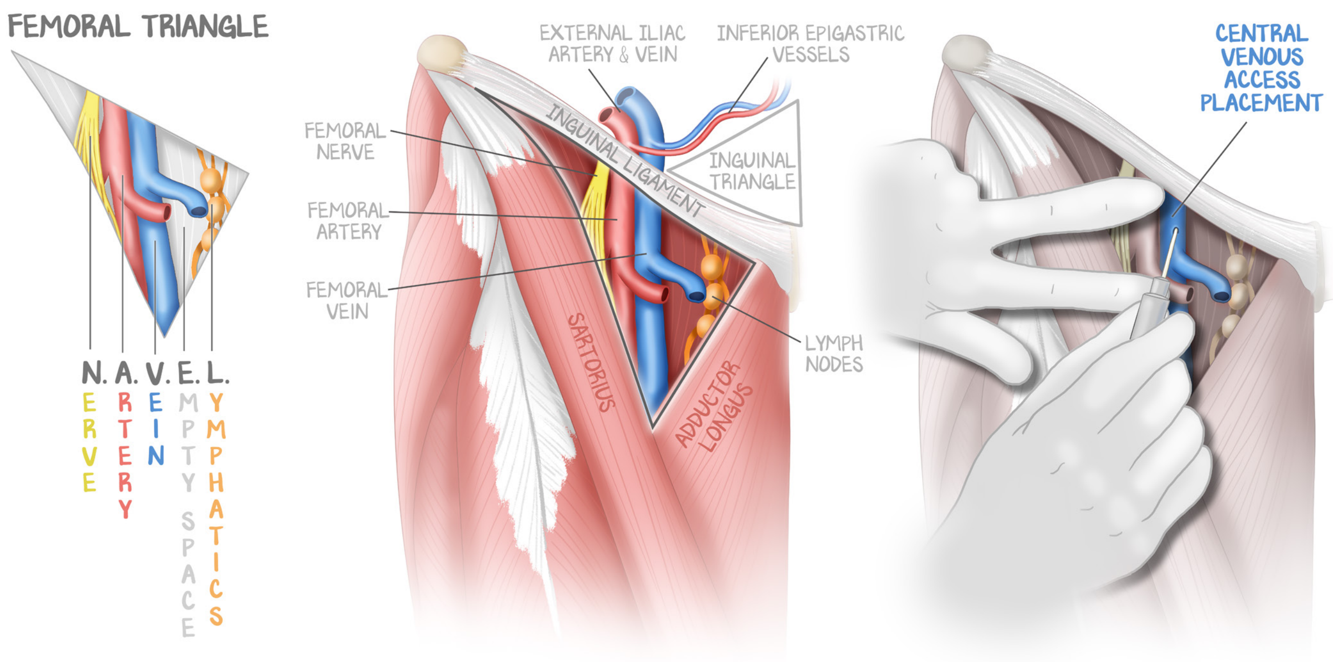


Figure 1.10: The Femoral Triangle
The femoral triangle is on the other side of the inguinal ligament. Just as the femoral artery, nerve, and vein leave the abdominal compartment (see the last illustration for the vessels), they exit into the femoral triangle. Bound by the sartorius, adductor longus, and the inguinal ligament, the femoral triangle contains the femoral nerve, artery, vein, and canal as they enter the thigh compartment. NAVEL, from lateral to medial, represents the order the structures appear—Nerve, Artery, Vein, Empty Space, and Lymphatics. This is relevant for a number of reasons, one of which is the placement of a central catheter without ultrasound guidance. By placing the non-dominant hand on the femoral artery, if positioned correctly and on the proper side (the non-dominant hand should be lateral to the vein) the dominant hand can then attempt line placement with confidence that it won't harm the artery or the nerve.

Transition

This lesson should arm you with the information you need to discuss problems with the bowel and the abdominal wall, which we cover in the next lesson. When novice learners encounter this information for the first time, it is an arduous process to communicate what each thing is. Most learners memorize the boundaries and don't ever put them into context. We spent a lot of time in this lesson to make the next one faster.